IAP7 Rec'd PCT/PTO 17 MAY 2006

PTO/SB/21 (09-04)
Approved for use through 07/31/2006. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

TRANSMITTAL FORM (to be used for all correspondence after initial filing)		Application Number	10/576,171
		Filing Date	18 April 2006
		First Named Inventor	Andrey V. Belogolovyi
		Art Unit	
		Examiner Name	
Total Number of Pages in This Submission	38	Attorney Docket Number	42P21070

ENCLOSURES (Check all that apply)

- [ ] Fee Transmittal Form
  - [ ] Fee Attached
- [ ] Amendment/Reply
  - [ ] After Final
  - [ ] Affidavits/declaration(s)
- [ ] Extension of Time Request
- [ ] Express Abandonment Request
- [ ] Information Disclosure Statement
- [x] Certified Copy of Priority Document(s)
- [ ] Reply to Missing Parts/ Incomplete Application
  - [ ] Reply to Missing Parts under 37 CFR 1.52 or 1.53
- [ ] Drawing(s)
- [ ] Licensing-related Papers
- [ ] Petition
- [ ] Petition to Convert to a Provisional Application
- [ ] Power of Attorney, Revocation Change of Correspondence Address
- [ ] Terminal Disclaimer
- [ ] Request for Refund
- [ ] CD, Number of CD(s) ____________
  - [ ] Landscape Table on CD
- [ ] After Allowance Communication to TC
- [ ] Appeal Communication to Board of Appeals and Interferences
- [ ] Appeal Communication to TC (Appeal Notice, Brief, Reply Brief)
- [ ] Proprietary Information
- [ ] Status Letter
- [x] Other Enclosure(s) (please Identify below): Return Receipt Postcard

Remarks: Express Mail No. EV 841 072 508 US

SIGNATURE OF APPLICANT, ATTORNEY, OR AGENT

Firm Name	BLAKELY, SOKOLOFF, TAYLOR AND ZAFMAN, LLP 12400 Wilshire Boulevard, Seventh Floor, Los Angeles, CA 90025-1030
Signature	[signature]
Printed name	**Lester J. Vincent**
Date	**17 May 2006** — Reg. No. **31,460**

CERTIFICATE OF TRANSMISSION/MAILING

I hereby certify that this correspondence is being facsimile transmitted to the USPTO or deposited with the United States Postal Service with sufficient postage as first class mail in an envelope addressed to: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450 on the date shown below:

Signature	Jessica Savage		
Typed or printed name	Jessica Savage	Date	17 May 2006

РОСПАТЕНТ
Федеральное государственное учреждение
«Федеральный институт
промышленной собственности
Федеральной службы по интеллектуальной
собственности, патентам и товарным знакам»
(ФГУ ФИПС)
Бережковская наб., 30, корп. 1, Москва, Г-59, ГСП-5, 123995
Телефон 240- 60- 15. Телекс 114818 ПДЧ. Факс 234- 30- 58

Наш № 20/12-228

«26» апреля 2006 г.

СПРАВКА

Федеральный институт промышленной собственности (далее - Институт) настоящим удостоверяет, что приложенные материалы являются точным воспроизведением первоначального заявления, описания, формулы, реферата и чертежей (если имеются) международной заявки № PCT/RU2005/000272, поданной в Институт как в Получающее ведомство в соответствии с Договором о патентной кооперации 18 мая 2005 года (18.05.2005).

Заведующий отделом 20 **А.Л.Журавлев**

Копия для получающего ведомства

300604

1/4

PCT REQUEST

Original (for **SUBMISSION**)

0	**For receiving Office use only**	
0-1	International Application No.	PCT/RU2005/000272
0-2	International Filing Date	18 May 2005 (18.05.2005)
0-3	Name of receiving Office and "PCT International Application"	~~RO/RU~~ МЕЖДУНАРОДНАЯ ЗАЯВКА PCT PCT INTERNATIONAL APPLICATION

0-4	**Form PCT/RO/101 PCT Request**	
0-4-1	Prepared Using	PCT-SAFE [EASY mode] Version 3.50 (Build 0002.170)
0-5	**Petition** The undersigned requests that the present international application be processed according to the Patent Cooperation Treaty	
0-6	**Receiving Office (specified by the applicant)**	Federal Service on Intellectual Property, Patents and Trademarks (Russian Federation) (RO/RU)
0-7	**Applicant's or agent's file reference**	300604
I	**Title of Invention**	A MODULATION SCHEME FOR COMMUNICATION ENVIRONMENT
II	**Applicant**	
II-1	This person is	applicant only
II-2	Applicant for	all designated States except US
II-4	Name	INTEL CORPORATION
II-5	Address	2200 Mission College Boulevard Santa Clara, California 95052 United States of America
II-6	State of nationality	US
II-7	State of residence	US
III-1	**Applicant and/or inventor**	
III-1-1	This person is	applicant and inventor
III-1-2	Applicant for	US only
III-1-4	Name (LAST, First)	BELOGOLOVYI, Andrey Vladimirovich
III-1-5	Address	Turbinnaja str 35, Building 1, Apt. 3 198097 Saint-Petersburg Russian Federation
III-1-6	State of nationality	RU
III-1-7	State of residence	RU

ПОЛУЧЕНО
18 МАЙ 2005 1084+КОП-дuek

300604

PCT REQUEST

Original (for **SUBMISSION**)

III-2	**Applicant and/or inventor**	
III-2-1	This person is	applicant and inventor
III-2-2	Applicant for	US only
III-2-4	Name (LAST, First)	CHERNYSHEV, Vladislav A.
III-2-5	Address	Gastello 11-45 196066 Saint-Petersburg Russian Federation
III-2-6	State of nationality	RU
III-2-7	State of residence	RU
III-3	**Applicant and/or inventor**	
III-3-1	This person is	applicant and inventor
III-3-2	Applicant for	US only
III-3-4	Name (LAST, First)	TAUBIN, Felix Aleksandrovich
III-3-5	Address	Tankista Hrustitskogo Str 33, Apt 6 190000 Saint-Petersburg Russian Federation
III-3-6	State of nationality	RU
III-3-7	State of residence	RU
IV-1	**Agent or common representative; or address for correspondence** The person identified below is hereby/has been appointed to act on behalf of the applicant(s) before the competent International Authorities as:	agent
IV-1-1	Name	LAW FIRM "GORODISSKY & PARTNERS" LTD
IV-1-2	Address	EGOROVA Galina Borisovna MITS Alexander Vladimirovich et al. B.Spasskaya str., 25, stroenie 3 129010 Moscow Russian Federation
V	**DESIGNATIONS**	
V-1	**The filing of this request constitutes under Rule 4.9(a), the designation of all Contracting States bound by the PCT on the international filing date, for the grant of every kind of protection available and, where applicable, for the grant of both regional and national patents.**	
VI-1	**Priority Claim**	NONE
VII-1	**International Searching Authority Chosen**	European Patent Office (EPO) (ISA/EP)

PCT REQUEST

Original (for **SUBMISSION**)

VIII	**Declarations**	Number of declarations	
VIII-1	Declaration as to the identity of the inventor	-	
VIII-2	Declaration as to the applicant's entitlement, as at the international filing date, to apply for and be granted a patent	-	
VIII-3	Declaration as to the applicant's entitlement, as at the international filing date, to claim the priority of the earlier application	-	
VIII-4	Declaration of inventorship (only for the purposes of the designation of the United States of America)	-	
VIII-5	Declaration as to non-prejudicial disclosures or exceptions to lack of novelty	-	
IX	**Check list**	number of sheets	electronic file(s) attached
IX-1	Request (including declaration sheets)	4	✓
IX-2	Description	16	-
IX-3	Claims	5	-
IX-4	Abstract	1	✓
IX-5	Drawings	7	-
IX-7	TOTAL	33	
	Accompanying Items	paper document(s) attached	electronic file(s) attached
IX-8	Fee calculation sheet	✓	-
IX-17	PCT-SAFE physical media	-	✓
IX-19	**Figure of the drawings which should accompany the abstract**		
IX-20	**Language of filing of the international application**	English	
X-1	**Signature of applicant, agent or common representative**		
X-1-1	Name	LAW FIRM "GORODISSKY & PARTNERS" LTD	
X-1-2	Name of signatory	EGOROVA Galina Borisovna	
X-1-3	Capacity	Chief of Filing Department	

PCT REQUEST

Original (for **SUBMISSION**)

FOR RECEIVING OFFICE USE ONLY

10-1	**Date of actual receipt of the purported international application**	18 May 2005 (18.05.2005)
10-2	**Drawings:**	
10-2-1	Received	X
10-2-2	Not received	
10-3	**Corrected date of actual receipt due to later but timely received papers or drawings completing the purported international application**	
10-4	**Date of timely receipt of the required corrections under PCT Article 11(2)**	
10-5	**International Searching Authority**	ISA/EP
10-6	**Transmittal of search copy delayed until search fee is paid**	

FOR INTERNATIONAL BUREAU USE ONLY

11-1	**Date of receipt of the record copy by the International Bureau**	

PCT

Original (for **SUBMISSION**)

13-2-3	Validation messages Names	Green? Applicant 1:Telephone No. missing
	Validation messages Names	Green? Applicant 1:Facsimile No. missing
	Validation messages Names	Green? Agent 1:Telephone No. missing
	Validation messages Names	Green? Agent 1:Facsimile No. missing
13-2-4	Validation messages Priority	Green? No priority of an earlier application has been claimed. Please verify
13-2-7	Validation messages Contents	Yellow! The power of attorney or a copy of the general power of attorney will need to be furnished unless all applicants sign the request form.
	Validation messages Contents	Green? Figure of the drawings which should accompany the abstract not specified. Please verify.

A MODULATION SCHEME FOR COMMUNICATION ENVIRONMENT

BACKGROUND

[0001] A communication environment generally refers to a group of interconnected wired and/or wireless devices such as, for example, laptops, mobile phones, servers, fax machines, printers, etc, which may send/receive data. The devices may transfer data in the form of a signal over a communication channel provisioned between devices. The devices may process the data to efficiently transfer the data over a communication channel. Such processing may include, for example, coding and modulating.

BRIEF DESCRIPTION OF THE DRAWINGS

[0002] The invention described herein is illustrated by way of example and not by way of limitation in the accompanying figures. For simplicity and clarity of illustration, elements illustrated in the figures are not necessarily drawn to scale. For example, the dimensions of some elements may be exaggerated relative to other elements for clarity. Further, where considered appropriate, reference labels have been repeated among the figures to indicate corresponding or analogous elements.

[0003] FIG. 1 illustrates an embodiment of a communication system comprising a transceiver and a communication channel.

[0004] FIG. 2 illustrates an embodiment of a transmitter of the transceiver of FIG. 1.

[0005] FIG. 3 illustrates an embodiment of a bit-to-symbol mapping table used by the mapper of Fig. 2.

[0006] FIG. 4 depicts a flow-chart illustrating an

operation of the mapper of Fig. 2.

[0007] FIG. 5A illustrates an embodiment of a receiver of FIG.1

[0008] FIG. 5B depicts a reliability assignment used by the receiver of FIG. 5A.

[0009] FIG. 6 illustrates an embodiment of a network system.

DETAILED DESCRIPTION

[0010] The following description describes a communication environment. In the following description, numerous specific details such as logic implementations, resource partitioning/sharing/duplication implementations, types and interrelationships of system components, and logic partitioning/integration choices are set forth in order to provide a more thorough understanding of the present invention. It will be appreciated, however, by one skilled in the art that the invention may be practiced without such specific details. In other instances, control structures, gate level circuits, and full software instruction sequences have not been shown in detail in order not to obscure the invention. Those of ordinary skill in the art, with the included descriptions, will be able to implement appropriate functionality without undue experimentation.

[0011] References in the specification to "one embodiment", "an embodiment", "an example embodiment", etc., indicate that the embodiment described may include a particular feature, structure, or characteristic, but every embodiment may not necessarily include the particular feature, structure, or characteristic. Moreover, such phrases are not necessarily referring to the same embodiment. Further, when a particular feature,

structure, or characteristic is described in connection with an embodiment, it is submitted that it is within the knowledge of one skilled in the art to effect such feature, structure, or characteristic in connection with other embodiments whether or not explicitly described.

[0012] Embodiments of the invention may be implemented in hardware, firmware, software, or any combination thereof. Embodiments of the invention may also be implemented as instructions stored on a machine-readable medium, which may be read and executed by one or more processors. A machine-readable medium may include any mechanism for storing or transmitting information in a form readable by a machine (e.g., a computing device). For example, a machine-readable medium may include read only memory (ROM); random access memory (RAM); magnetic disk storage media; optical storage media; flash memory devices; electrical, optical, acoustical or other forms of propagated signals (e.g., carrier waves, infrared signals, digital signals, etc.), and others. Further, firmware, software, routines, instructions may be described herein as performing certain actions. However, it should be appreciated that such descriptions are merely for convenience and that such actions in fact result from computing devices, processors, controllers, or other devices executing the firmware, software, routines, instructions, etc.

[0013] An embodiment of a communication system is illustrated in FIG. 1. The communication system may comprise a transceiver 100 and a communication medium 150. The transceiver 100 may transmit and receive signals on the communication medium 150. The communication medium 150 may represent a wired medium such as a twisted copper pair, optical fiber, and wireless medium such as an air

medium. The transceiver 100 may be used, for example, in network interface cards (NIC), physical layer devices (PHYs) etc. In one embodiment, the transceiver 100 may comprise a transmitter 120, a receiver 130, and a front end 140.

[0014] The receiver 130 may process a received signal before sending the extracted data bits for further processing, for example, to a switch, router, or any device configured to receive data bits. In one embodiment, the receiver 130 may decode the signal and extract the data bits. The receiver 130 may receive, for example, a pulse amplitude modulated (PAM-16) symbol, process the symbol using techniques such as descrambling and error correcting, and then send the extracted data bits for further processing.

[0015] The front end device 140 may comprise one or more interface units or ports to couple the transmitter 120 and the receiver 130 to the communication medium 150. The front end device 140 may comprise data converters, amplifiers, and such other electronic circuits. In one embodiment, the front device 140 may receive a stream of symbols from the transmitter 120, convert the symbols into an appropriate signal such as a pulse using a data converter, and may transmit the signals on the communication medium 150. Similarly, the front end device 140 may convert a received signal into an appropriate format for the receiver 130.

[0016] The transmitter 120 may receive a bit stream, process the bit stream to generate one or more symbols, and then provide the symbols to the front end device 140. In one embodiment, the transmitter 120 may process the bit stream using techniques such as framing, scrambling, encoding, mapping, and pre-coding. The

transmitter 120 may modulate the bit stream, for example, using a pulse amplitude modulation (PAM) technique to transmit two or more bits of the bit stream in the form of a symbol corresponding to a voltage level of the pulse. Modulation techniques may be used, for example, to efficiently use the channel bandwidth. The transmitter 120 may include forward error correction code to facilitate error detection and correction at the receiving end, before transmitting the signal over the communication medium 150.

[0017] In one embodiment, during the start-up, a receiver that may eventually receive signals from the transmitter 120 may measure the signal-to-noise ratio (SNR) corresponding to the communication medium 150 and may then determine the allowable bit error rate (BER) at the measured SNR. The transmitter 120 may receive, from the receiver, the characteristics of the communication medium 150 before transmitting the information signal. In one embodiment, the transmitter 120 may determine the PAM levels or the number of symbols in a symbol set based on the allowable bit error rate at the measured SNR.

[0018] An embodiment of the transmitter 120 is illustrated in FIG. 2. The transmitter 120 may comprise a framer 210, a scrambler 220, an encoder 240, a mapper 250, and a pre-coder 280.

[0019] The framer 210 may receive the bit stream and generate one or more frames by dividing the bit stream into smaller pieces of pre-specified size and adding control bits. The framer 210 may add control bits such as synchronization bits, cyclic redundancy check bits, and stuffing bits to cause frame alignment, error detection, and to mark the frame boundaries. In one embodiment, each frame may comprise a payload bits and control bits.

[0020] The scrambler 220 may receive the frames, scramble the payload bits, and generate one or more scrambled frames. The scrambler 220 may send first K bits of a scrambled frame to the encoder 240 and the remaining un-coded bits (un-coded bit stream) of the scrambled frame to the mapper 250. In one embodiment, the scrambler 220 may generate scrambled frames using filter structures that may convolve the payload bits in the scrambled frames.

[0021] The encoder 240 may encode the first K bits using techniques such as low density parity check (LDPC) coding or a convolution coding or such other coding techniques. In one embodiment, the encoder 240 may receive K bits from the scrambler 220 and generate a coded bit stream comprising N bits (N greater than K) using LDPC coding. The encoder 240 may send the coded bit stream of N bits to the mapper 250. The encoder 240 may generate the coded bit stream comprising N bits by adding (N-K) bits to the K bits to enable forward error correction at the receiver side of another transceiver. For example, the encoder 240 may receive 1020 bits (=K) and generate 1344 bits (=N) by performing operations such as modulo 2 multiplication of 1020 bits and the values of a LDPC code generator matrix. LDPC is described at least in R.G. Gallager, Low-density parity-check codes, IRE Trans. Inform. Theory, vol. 8, pp. 21-28, Jan.1962.

[0022] The mapper 250 may generate a combination by combining the bits selected from the coded bit stream of the encoder 240 and the un-coded bit stream of the scrambler 220. The mapper 250 may generate a symbol corresponding to the combination using a modulation technique such as the pulse amplitude modulation (PAM). Each combination may be mapped into a symbol and the mapper 250 may generate a stream of symbols corresponding

to the combinations.

[0023] In one embodiment, the mapper 250 may receive N/3 bits of the un-coded bit stream and N bits of the coded bit stream and determine a symbol using, for example, PAM-16 scheme. For example, the mapper 250 may select one bit from the un-coded bit stream, three bits from the coded bit stream, generate a combination comprising four bits, and determine a symbol corresponding to the combination. In one embodiment, the mapper 250 may produce N/3 combinations and map each combination may correspond to one of the 16 symbols.

[0024] In one embodiment, the mapper 250 may generate N/3 PAM symbols for each scrambled frame comprising K+N/3 bits. For example, the mapper 250 may generate 448 symbols if the value of N equals 1344. Such a modulation technique may enable four data bits to be transmitted per symbol as compared to three bits/symbol in the case of a PAM-8 modulation scheme. Thus, using PAM-16 scheme may reduce the sampling rates and may thus enable lesser computational resources to be used at the corresponding receiver.

[0025] In one embodiment, the number of symbols or PAM levels may be chosen based on an allowable bit error rate at the measured signal-to-noise ratio (SNR) of the communication channel 150. In one embodiment, the mapper 250 may generate combinations comprising the un-coded bits and the coded bits, for example, to maintain the bit error rate value below the allowable bit error rate value, increase the transmission speed, and decrease the sampling rate.

[0026] The number of the un-coded bits and the coded bits may be selected based on, for example, transmission speed, allowable error floor values etc. In

one embodiment, the transmission speed may be increased by increasing the number of information bits in each combination. The number of information bits may be increased by combining both the un-coded bits and the coded bits to produce a combination. In one embodiment, the information bits transmitted/symbol may be determined using Equation (1) shown below.

[0027] Information bits/symbol=coded bits of the combination*code rate R + un-coded bits of the combination Equation (1)

[0028] The code rate R may equal the ratio of the bits provided as input to the encoder 240 and the bits received as output from the encoder 240. In the above example, the code rate R may equal 0.75892 (=1020/1344) approximately. The mapper 250 may generate 3.27 (=3 x 0.75892 + 1) information bits/symbol by choosing one un-coded bit and three coded bits. However, if all four bits are selected from the coded bit stream the mapper 250 may generate only 3.03 (=4 x 0. 75892) information bits/symbol. Thus, the mapper 250 may produce a combination by selecting one bit and three bits respectively from the un-coded bit stream and the coded bit stream. However, the number of un-coded bits to be included in the combination may be determined based on the allowable bit error rate (BER) at the measured SNR of the communication medium 150.

[0029] The sampling rate SR corresponding to a data rate of 10Gigabit transmission may be computed using Equation (2) shown below.

[0030] SR=(10x10exp+9)/(4*Information bits/symbol) .. .Equation (2)

[0031] The exp , + , x , and / respectively represent exponential, addition, multiplication and

division operators. In the above example, the sampling rate SR may equal 762 MHz ((10 x 10 exp+9)/(4*3.27)). Using PAM-16 modulation may result in a SR that is substantially close to an optimum sampling rate point of a copper medium on a curve drawn with bit error rate and the SNR as the parameters. The sampling rate corresponding to other PAM schemes such as PAM-8, PAM-12 or PAM-25 may have a larger deviation from the optimum sampling rate. As the sampling rate is substantially close to optimum value the computational resources that may be employed to process the PAM-16 modulated signal may be less compared to other PAM schemes.

[0032] The mapper 250 may store, for example, a bit-to-symbol mapping table 300 comprising one or more entries. Each entry, for example, may comprise an un-coded portion, coded portion, and a corresponding symbol. In one embodiment, the mapper 250 may comprise a content addressable memory, which may perform comparisons to produce a corresponding symbol.

[0033] In one embodiment, the mapper 250 may use the PAM-16 scheme and the number of symbols may equal sixteen. Each of the sixteen symbols corresponding to a combination comprising four bits (one un-coded bit and three coded bits) may correspond to a value such as +15, +13, +11 -13, and -15.

[0034] In one example, the mapper 250 may select three bits from the coded bit stream of 1344 bits and one bit from the un-coded bit stream of 448 bits. The mapper 250 may compare the first bit of the combination representing the un-coded bit with the corresponding bit in the un-coded portion of the bit-to-symbol mapping table and the second, third, and the fourth bits of the combination representing the coded bits with the

respective bits in the coded portion of the bit-to-symbol mapping table.

[0035] For example, the combination may equal 0001, the un-coded bit may equal 0 (first bit from left), and the coded bits may equal 001 (second, third, and fourth bits from left). The mapper250 may use the combination equaling 0001 as a key, search the mapping table for a matching entry that equals 0001, and then produce a symbol corresponding to the matching entry. For example, the symbol corresponding to the combination of 0001 may equal a value of +13. The mapper 250 may then send the symbol to the pre-coder 280.

[0036] The pre-coder 280 may receive a stream of symbols from the mapper 250 and may perform operations to substantially reduce the unwanted effects of the communication medium 150. The pre-coder 280 may use the allowable bit rate and the measured SNR of the communication medium150 to perform operations such as linear equalization.

[0037] The pre-coder 280 may use pre-coding filters to perform operations such as linear equalization to reduce the unwanted effect that may be caused due to undesired characteristics of the communication medium 150. Such an approach may cause the signal to be transmitted with higher signal to noise ratio (SNR) values. In one embodiment, the pre-coder 280 may use Tomlinson-Harashima pre-coder (THP).

[0038] An embodiment of the bit-to-symbol mapping table 300 is illustrated in FIG. 3. The bit-to-symbol mapping table 300 may be stored in the mapper 250 and the table 300 may comprise three columns 301, 304, and 309 respectively representing the un-coded portion, the coded portion, and the corresponding symbol and sixteen rows 310

through 390.

[0039] The row 315 is shown comprising {0, 000, and +15} respectively representing the un-coded portion, the coded-portion, and the corresponding symbol. For example, if the mapper 250 receives an un-coded bit equaling 0 and the coded bits equaling 000, the mapper 250 may produce a combination equaling 0000, which may be used as a key to search the bit-to-symbol mapping table 300 for an entry equaling 0000. As may be observed, the combination 0000 matches with the entry in the row 315 and the corresponding symbol equals +15. The symbol equaling +15 may be sent to the pre-coder 280.

[0040] The un-coded-portion, the coded portion, and the symbol in rows 320-390 respectively equal {0, 001, +13}, {0, 011, +11}, {0, 010, +9}, {0, 110, +7}, {0, 111, +5}, {0, 101, +3}, {0, 100, +1}, {1, 100, -1}, {1, 101, -3}, {0, 111, -5}, {1, 110, -7}, {1, 010, -9}, {0, 011, -11}, {0, 001, -13}, and {1, 000, -15}. The mapper 250 may use the entries to generate a corresponding symbol.

[0041] FIG. 4 illustrates operation of an embodiment of the mapper 250. In block 410, the mapper 250 may receive an un-coded bit stream and a coded bit stream from the scrambler 220 and the encoder 240. In one embodiment, the encoder 240 may generate a coded bit stream comprising N bits (=1344) bits after receiving 1020 bits from the scrambler 220 and the scrambler 220 may send an un-coded bit stream comprising N/3 bits (=448) to the mapper 250.

[0042] In block 420, the mapper 250 may select a pre-specified number of coded bits and un-coded bits respectively from a coded bit stream and an un-coded bit stream. In one embodiment, the mapper 250 may select one bit from the un-coded bit stream and three bits from the

coded bit stream.

[0043] In block 440, the mapper 250 may produce a combination comprising the un-coded bits and the coded bits. In one embodiment, the mapper 250 may produce a combination 0001 after selecting, for example, a 0 and 001 respectively from the un-coded bit stream and the coded bit stream.

[0044] In block 470, the mapper 250 may determine a symbol corresponding to the combination. In one embodiment, the mapper 250 may compare the combination with each entry in the bit-to-symbol mapping table 300 until a matching entry is found and the symbol corresponding to the matching entry may represent the corresponding combination. In one embodiment, entries (0000), (0001), (0011), (0010), (0110), (0111), (0101), (0100), (1000), (1001), (1011), (1010), (1110), (1111), (1101), and (1100) may respectively correspond to symbols +15, +13, +11, +9, +7, +5, +3, +1, -1, -3, -5, -7, -9, -11, -13, and -15.

[0045] In block 490, the mapper 250 may send the corresponding symbol. In one embodiment, the mapper 250 may send one or more symbols to the pre-coder 280.

[0046] Thus, the transmitter 120 may generate a symbol enabling transfer of information at higher speeds in communication environments using technologies such as 10 giga bit Ethernet (10gbE) or more.

[0047] An embodiment of the receiver 130 is illustrated in FIG. 5A. The receiver 130 may comprise a de-framer 510, a descrambler 520, a de-mapper 530, and a decoder 540.

[0048] The de-mapper 530 may receive a symbol from the communication medium 150 and generate a stream of coded bits and un-coded bits. In one embodiment, the de-

mapper 530 may receive N/3 symbols; generate an un-coded bit stream comprising N/3 bits, and a coded bit stream comprising N bits. For example, the de-mapper 530 may perform inverse operation of the mapper 250 to determine a combination corresponding to the symbol, send the un-coded bit of each combination to the descrambler 520 and the remaining coded bits of each combination to the decoder 540.

[0049] The decoder 540 may receive the coded bits, extract the bits from the coded bits by removing the redundant bits after performing operations such as error detection and correction, and send the extracted bits to the descrambler 520. In one embodiment, the decoder 540 may receive N coded bits, extract K bits (K<N) from the coded bit stream, and send K bits to the descrambler 520.

[0050] The decoder 540 may extract K bits from the coded bit stream based on a reliability assignment corresponding to each bit of the coded bit stream. The decoder 540 may improve decoding performance, for example, by minimizing errors using the reliability assignment. The decoding performance may, for example, represent the degree of confidence that each bit may be extracted with minimal errors that may satisfy the allowable error levels. The reliability assignments based on log-likelyhood ratios (LLR) allow the decoder 540 to extract the bits with minimum errors. The LLR based assignments may be computationally intensive. In one embodiment, the reliability assignment may be performed based on the scheme described below with reference to FIG. 5B.

[0051] The descrambler 520 may receive un-coded bit streams and the extracted bit stream respectively from the de-mapper 530 and the decoder 540, descramble the received bits to generate payload bits, generate frames,

and send the frames to the de-framer 510. In one embodiment, the descrambler 520 may generate payload bits using filter structures that may perform inverse operations performed by the scrambler 220.

[0052] The de-framer 510 may receive the frames and generate a bit stream representing the data. The de-framer 510 may remove control bits such as start bits and end bits, synchronizing bits, and stuff bits. The de-framer 510 may then send the bit stream representing the data to an adjacent device such as a router, a switch, a computer system, a handheld device, mobile device, or any such device intended to receive bit stream from the receiver 130 of transceiver 100.

[0053] An embodiment of reliability assignment used by the receiver 130 is depicted in FIG. 5B. The reliability assignment graph is shown comprising a most significant bit (MSB) or Bit-2 reliability assignment curve 560, Bit-1 reliability assignment curve 570, least significant (LSB) or Bit-0 reliability assignment curve 580 plotted with reference to symbol axis 591, and reliability axis 592.

[0054] The reliability axis 592 is shown indicating reliability values in the range (+2, to -2) that may be assigned to the corresponding bit based on the symbol being decoded. For example, if the receiver 130 receives a symbol equaling +13 (0001), the decoder 540 may decode the coded bits 0, 0, and 1 (MSB, Bit-1, and LSB respectively) of coded bits 001 with reliability values of -1.5, -0.5 and +1 respectively. Similarly, for a symbol -11, the decoder 540 may decode the bits 1, 1, and 1 (MSB, Bit-1, and LSB respectively) of coded bits 111 with reliability values of +1.5, +0.5, and +1 respectively. The reliability assignment based on the reliability

assignment graph may be efficient in terms of usage of computational resources.

[0055] An embodiment of a network system 600 is illustrated in FIG. 6. The network system 600 may comprise a network device 610 and a network 650. The network device 610 may correspond to a router, laptop computer, desktop computer, a hand held device, network interface card or any such devices that may be coupled to the network 650.

[0056] The network 650 may comprise one or more intermediate devices such as switches and routers, which may receive, process, and send the packets to an appropriate intermediate device. The network 650 may enable network devices such as the network device 610 to transmit and/or receive data. The intermediate devices of the network 650 may be configured to support TCP/IP, ATM and any such communication protocols. The network 650 may be coupled to the network devices such as the network device 610 via communication medium that may transfer packets corresponding to technologies such as 10G Ethernet.

[0057] The network device 610 may generate one or more packets and send the packets to other network devices coupled to the network 650. The network device 610 may receive packets from other network devices via the network 650. In one embodiment, the network device 610 may comprise a processor 612, memory 614, and a network interface 618. The processor 612 may provide the network interface with the bit stream in response to executing instructions and the memory 614 may store the instructions executed by the processor. The network interface 618 may comprise, for example, a network interface card embodying a transceiver such as transceiver 100.

[0058] In one embodiment, the transceiver 100 may communicate with the network 650 in accordance with the evolving 10GBase-T standard as defined by the IEEE 802.3an series of standards, however, other standards may be used as well. In some embodiments, the transceiver 100 may communicate with the network 650 using any type of medium such as but not limited to twisted pairs of copper wire, optic channels, wireless channels, power-line channels, acoustic/sonar channels, printed circuit board (PCB), backplanes, coaxial cable, or any other medium. For example, the communication medium 150 may be category 5, 6, 6a, or 7 network cabling and/or any other shielded or unshielded cabling.

[0059] The transceiver 100 may process the bit stream received from applications such as an e-mail or a file transfer application executed on the processor 612. A transmitter such as the transmitter 120 of transceiver 100 may receive the bit stream and generate symbols based on PAM-16 modulation technique as described above. The transmitter 120 may send the symbols to front end devices, which may convert the symbol into a corresponding signal such as amplitude modulated pulses and the signal may then be sent on a communication medium such as an Ethernet medium.

[0060] Certain features of the invention have been described with reference to example embodiments. However, the description is not intended to be construed in a limiting sense. Various modifications of the example embodiments, as well as other embodiments of the invention, which are apparent to persons skilled in the art to which the invention pertains are deemed to lie within the spirit and scope of the invention.

What is claimed is:

1. A method comprising:

producing a combination by selecting a pre-determined number of bits from two or more bit streams;

determining a symbol corresponding to the combination from a symbol set comprising at least sixteen symbols; and

transmitting a signal corresponding to the symbol at a rate of at least 10 giga bits per second over a communication medium.

2. The method of claim 1 a first bit stream comprises N bits and a second bit stream comprises N/3 bits.

3. The method of claim 2 the N bits are generated by encoding K bits using low density parity check coding technique.

4. The method of claim 1 the combination comprises four bits wherein one bit is selected from the N/3 bits and three bits is selected from the N bits, wherein the number of bits of the combination is based on an allowable bit error rate at a measured value of signal-to-noise ratio of the communication medium.

5. The method of claim 1 determining the symbol comprises selecting the symbol based on a bit-to-symbol mapping table.

6. The method of claim 5 the selecting comprises searching for a matching entry corresponding to the combination and producing the symbol corresponding to the matching entry.

7. The method of claim 1 further comprising:

generating a coded bit stream and an un-coded bit stream from a received signal;

decoding a coded bit stream to generate an extracted bit stream based on the reliability assignment values

determined empirically,

generating a bit stream representing data, and

sending the bit stream.

8. The method of claim 7 the reliability assignment values are chosen based on the bit position of the coded bit stream corresponding to the symbol being decoded and one or more pre-defined reliability assignment values.

9. An apparatus comprising:

a transmitter to produce a combination by selecting a pre-determined number of bits from one or more bit streams, to determine a symbol corresponding to the combination from a symbol set, wherein the symbol set comprises at least sixteen symbols;

a receiver to demodulate based on a reliability assignment, and

a front end device to transmit a signal corresponding to the symbol at a rate of at least 10 giga bits per second over a communication medium.

10. The apparatus of claim 9 wherein the transmitter comprises a mapper to receive a first bit stream comprising N bits and a second bit stream comprising N/3 bits.

11. The apparatus of claim 10 further comprises an encoder to generate N bits by encoding K bits using low density parity check coding technique.

12. The apparatus of claim 9 the transmitter comprises the mapper to generate the combination by selecting one bit out of the N/3 bits and three bits out of the N bits, wherein the number of bits of the combination is based on an allowable bit error rate at a measured value of signal-to-noise ratio of the communication medium.

13. The apparatus of claim 9 the transmitter

comprises the mapper to determine the symbol by selecting the symbol based on the bit-to-symbol mapping table.

14. The apparatus of claim 13 the mapper to select the symbol comprises a content addressable memory to search a matching entry corresponding to the combination and to produce the symbol corresponding to the matching entry.

15. The apparatus of claim 9 the receiver further comprising:

a de-mapper to generate a coded bit stream and an un-coded bit stream from a received signal;

a decoder to decode a coded bit stream to generate an extracted bit stream based on the reliability assignment values determined empirically, and

a de-framer to generate a bit stream representing data.

16. The apparatus of claim 15 the reliability assignment values are chosen based on the bit position of the coded bit stream corresponding to the symbol being decoded and one or more pre-defined reliability assignment values.

17. The apparatus of claim 9 corresponds to a transceiver.

18. A system comprising:

a network interface to generate and transfer a signal that is representative of a bit stream and that comprises symbols selected from at least one of sixteen symbols,

a processor to provide the network interface with the bit stream in response to executing instructions;

a memory to store the instructions executed by the processor.

19. The system of claim 18 wherein the

network interface is to generate the signal as an amplitude modulated signal having a rate of at least 10 giga bits per second.

20. The system of claim 19 the network interface further comprising a transmitter to produce a combination by selecting a pre-determined number of bits from one or more bit streams, to determine the symbol corresponding to the combination from a symbol set, wherein the symbol set comprises at least sixteen symbols; and

a front end device to transmit the signal corresponding to the symbol at a rate of at least 10 giga bits over the communication medium.

21. The system of claim 20 wherein the transmitter comprises a mapper to receive a first bit stream comprising N bits and a second bit stream comprising N/3 bits.

22. The system of claim 20 the transmitter comprises the mapper to generate the combination by selecting one bit out of the N/3 bits and three bits out of the N bits.

23. The system of claim 20 the transmitter comprises the mapper to determine the symbol by selecting the symbol based on the bit-to-symbol mapping table.

24. The system of claim 20 the mapper to select the symbol comprises a content addressable memory to search a matching entry corresponding to the combination and to produce the symbol corresponding to the matching entry.

25. The system of claim 19 the network interface further comprises a receiver comprising:

a de-mapper to generate a coded bit stream and an un-coded bit stream from a received signal;

a decoder to decode a coded bit stream to generate an extracted bit stream based on the reliability assignment values determined empirically, and

a de-framer to generate a bit stream representing data.

26. The system of claim 19 the network interface includes a network interface card.

27. The system of claim 26 the network interface card includes logic capable of communicating at least in accordance with 10GBase-T standard.

28. The system of claim 18 the system further includes at least one of a computer, a switch, a router, or a server.

ABSTRACT

According to an aspect of the present invention, a symbol corresponding to a combination may be determined from a symbol set comprising at least sixteen PAM symbols. A sample such as a pulse may be generated based on the symbol value and a train of such pulses may be transmitted at a rate of at least 10 giga bits per second over a communication medium comprising, for example, a twisted copper cable. The received signal may be demodulated based on the empirically determined reliability values.

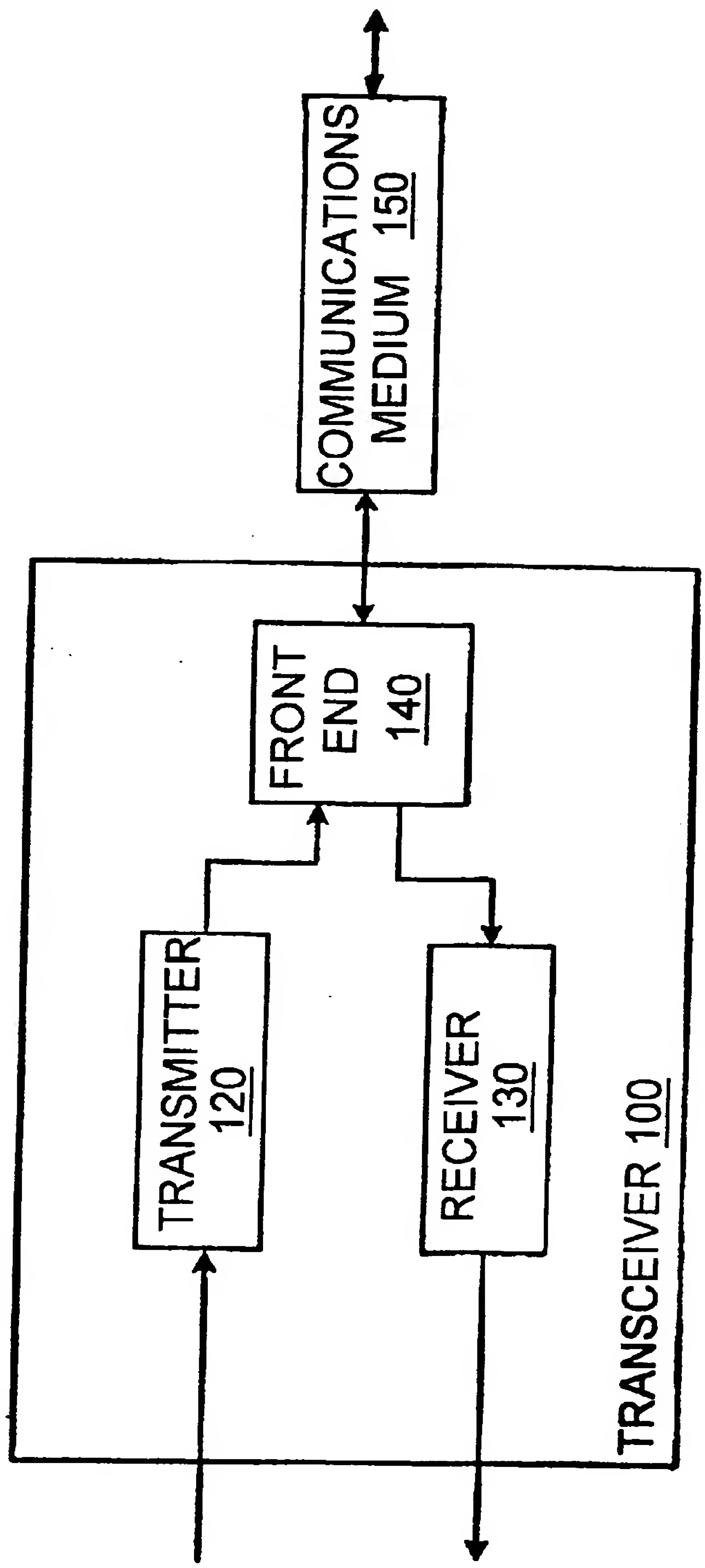
COMMUNICATIONS MEDIUM 150
FRONT END 140
TRANSMITTER 120
RECEIVER 130
TRANSCEIVER 100

FIG. 1

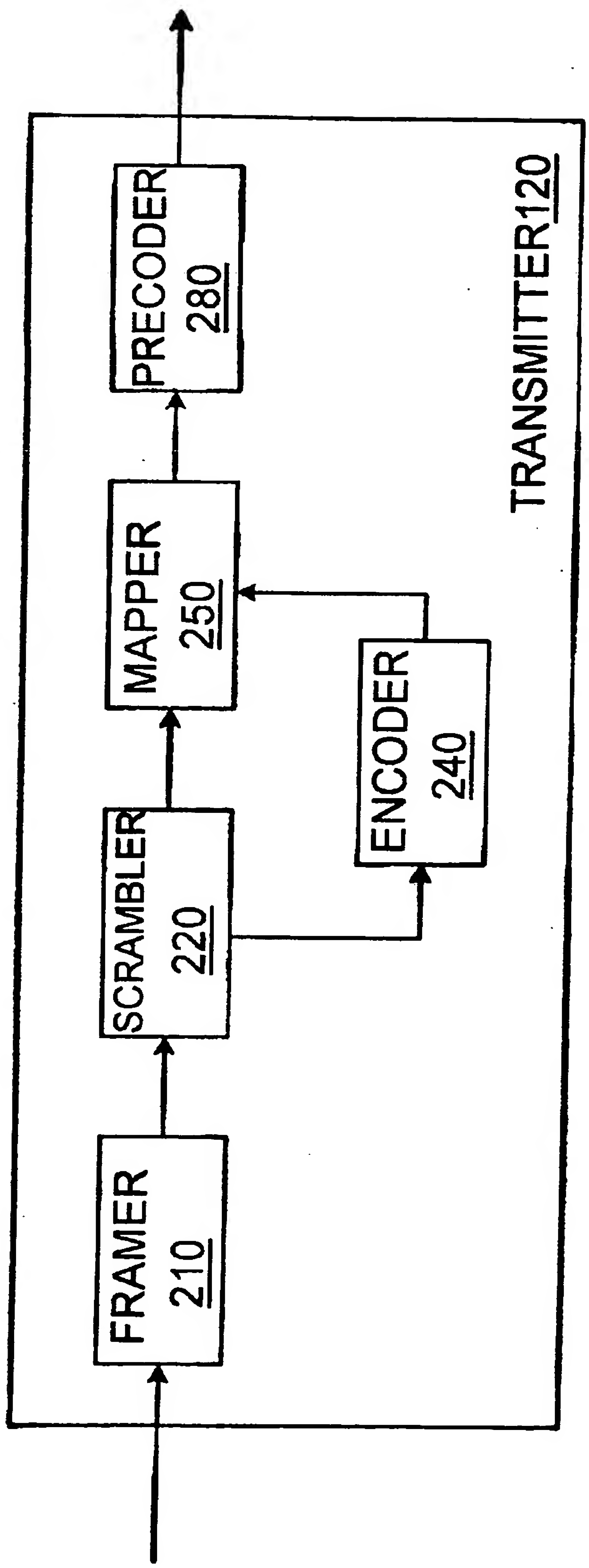
FRAMER 210
SCRAMBLER 220
ENCODER 240
MAPPER 250
PRECODER 280
TRANSMITTER120

FIG. 2

300

	301 UN-CODED PORTION	304 CODED PORTION	308 SYMBOL
310	UN-CODED PORTION	CODED PORTION	SYMBOL
315	0	000	+15
320	0	001	+13
325	0	011	+11
330	0	010	+9
335	0	110	+7
340	0	111	+5
345	0	101	+3
350	0	100	+1
355	1	000	-1
360	1	001	-3
365	1	011	-5
370	1	010	-7
375	1	110	-9
380	1	111	-11
385	1	101	-13
390	1	100	-15

FIG. 3

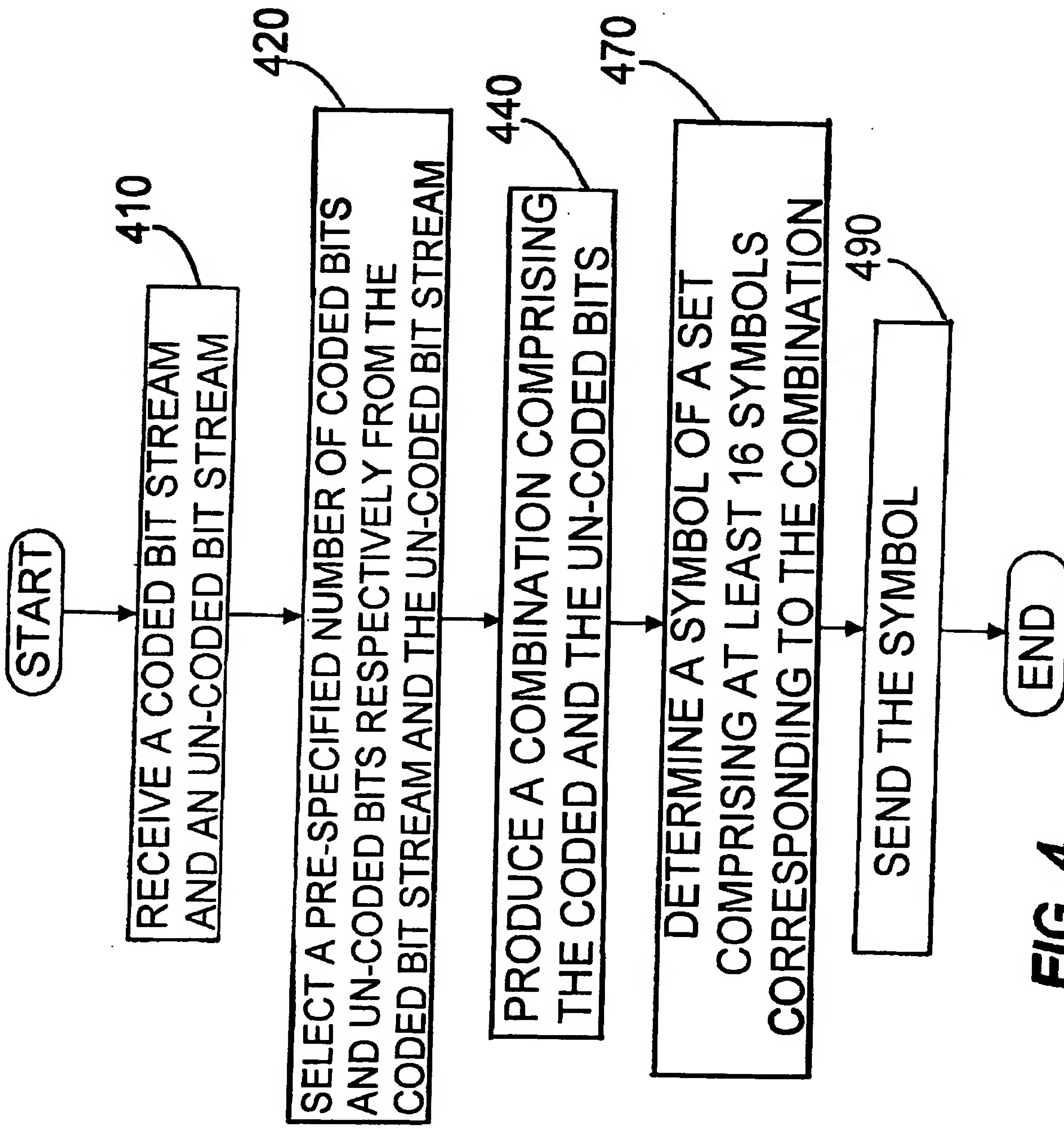
START
RECEIVE A CODED BIT STREAM AND AN UN-CODED BIT STREAM
410
SELECT A PRE-SPECIFIED NUMBER OF CODED BITS AND UN-CODED BITS RESPECTIVELY FROM THE CODED BIT STREAM AND THE UN-CODED BIT STREAM
420
PRODUCE A COMBINATION COMPRISING THE CODED AND THE UN-CODED BITS
440
DETERMINE A SYMBOL OF A SET COMPRISING AT LEAST 16 SYMBOLS CORRESPONDING TO THE COMBINATION
470
SEND THE SYMBOL
490
END

FIG. 4

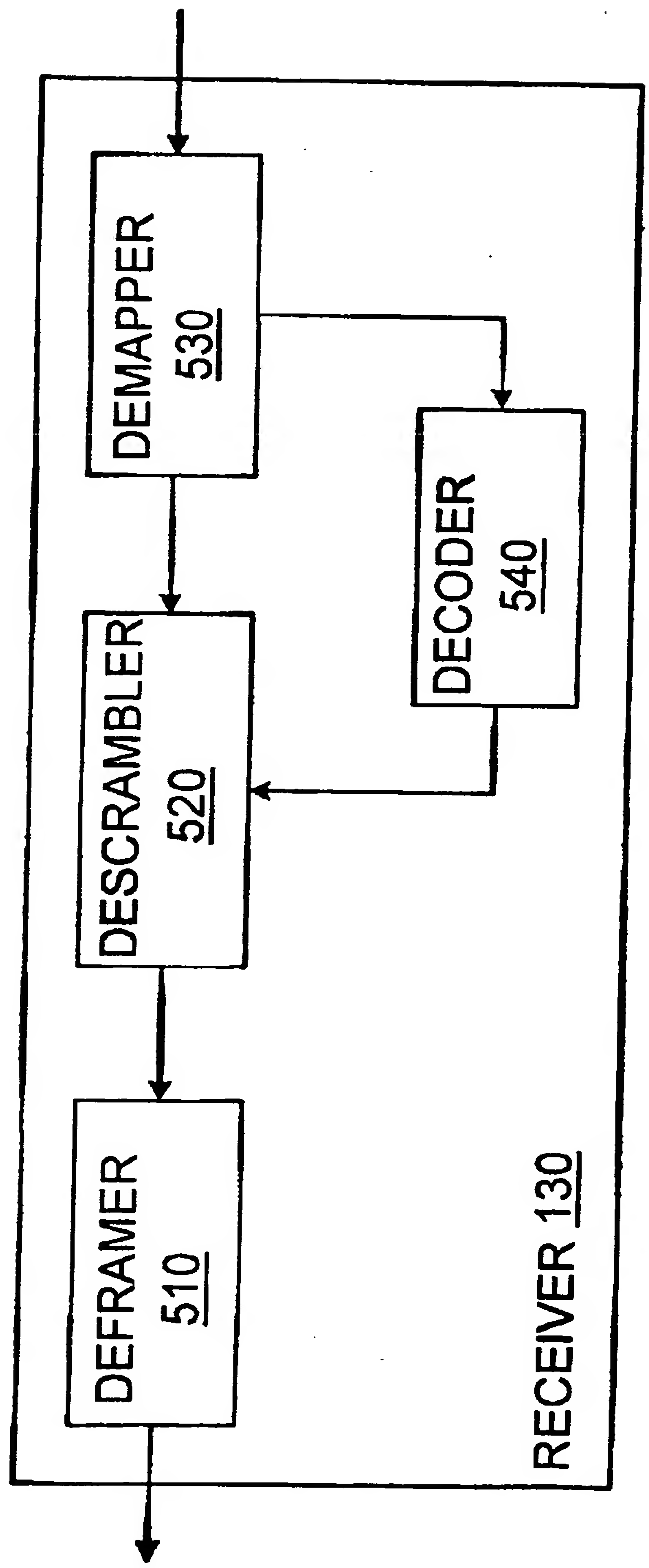
DEMAPPER
530
DECODER
540
DESCRAMBLER
520
DEFRAMER
510
RECEIVER 130

FIG. 5A

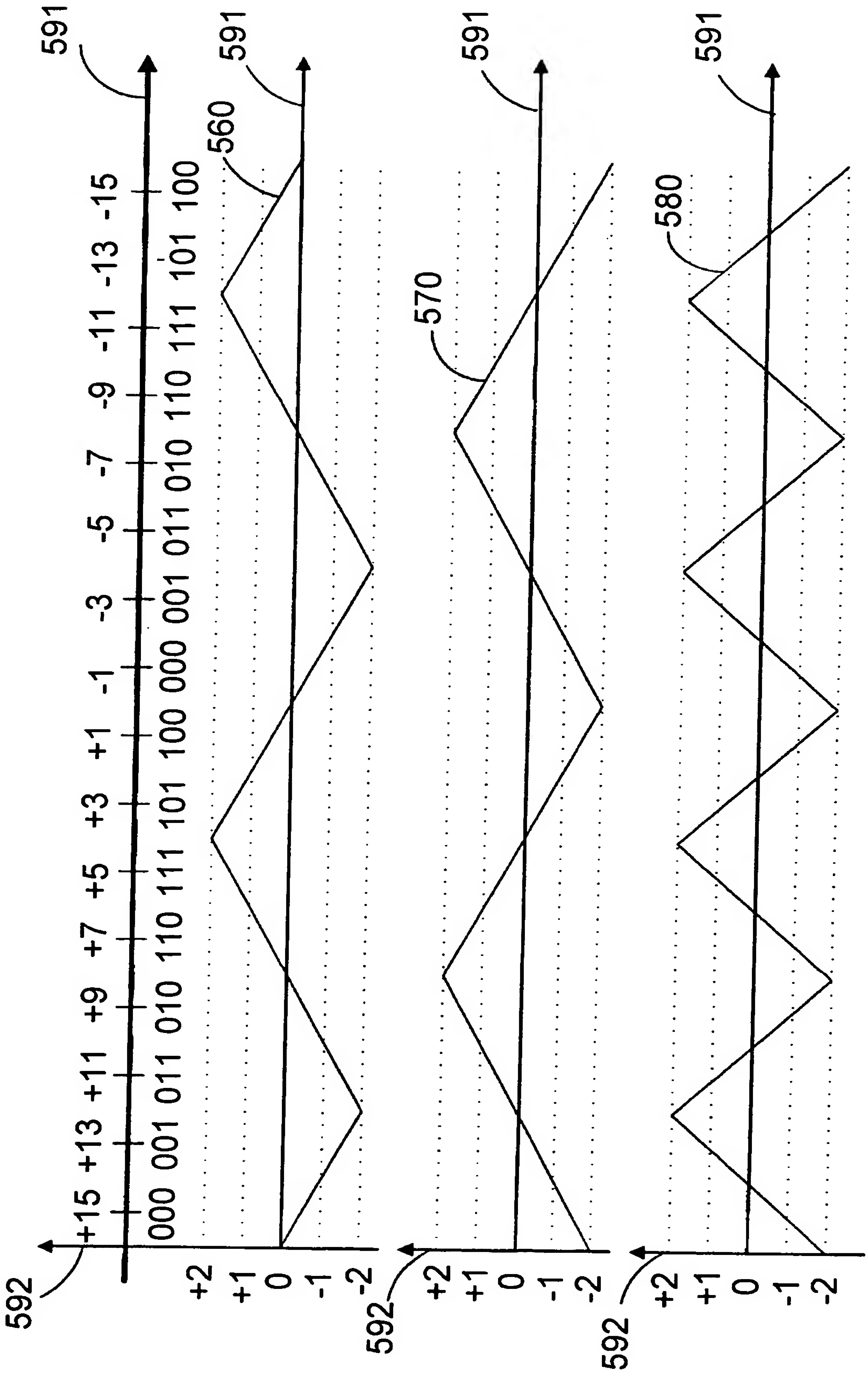
591
591
591
591
560
570
580
592
592
592
+15 +13 +11 +9 +7 +5 +3 +1 -1 -3 -5 -7 -9 -11 -13 -15
000 001 011 010 110 111 101 100 000 001 011 010 110 111 101 100
+2 +1 0 -1 -2
+2 +1 0 -1 -2
+2 +1 0 -1 -2

FIG. 5B

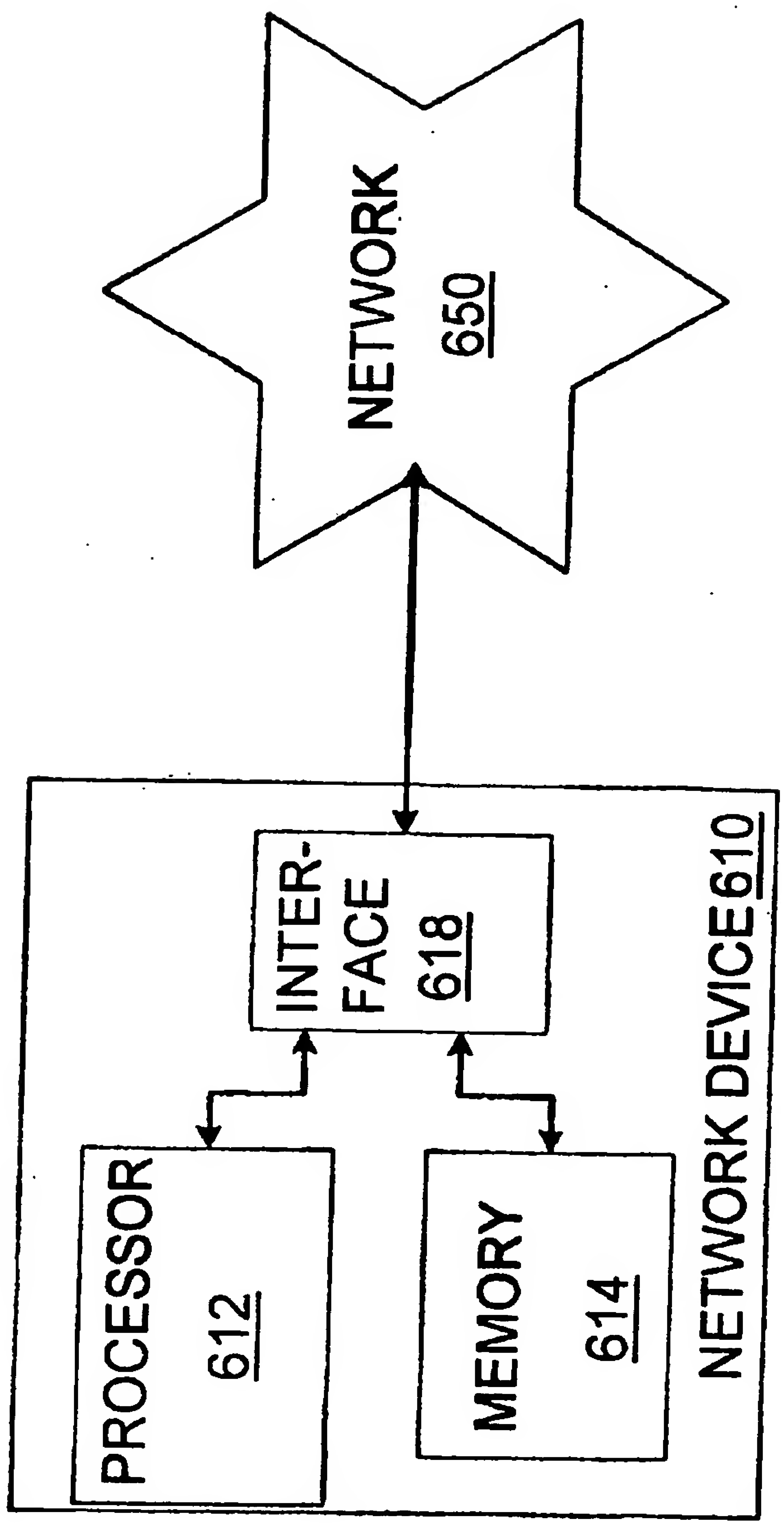
NETWORK
650
INTER-
FACE
618
PROCESSOR
612
MEMORY
614
NETWORK DEVICE 610

FIG. 6

According to an aspect of the present invention, a symbol corresponding to a combination may be determined from a symbol set comprising at least sixteen PAM symbols. A sample such as a pulse may be generated based on the symbol value and a train of such pulses may be transmitted at a rate of at least 10 giga bits per second over a communication medium comprising, for example, a twisted copper cable. The received signal may be demodulated based on the empirically determined reliability values.